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To: Dr. D. Mills
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AVAILABILITY OF DATA ON POLE TESTING AND TREATING

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ABSTRACT

An assessment was made to determine if sufficient data were available to evaluate the effectiveness of Ontario Hydro's wood pole retreatment program. The ultimate goal of this evaluation is to recommend continuation, improvement or discontinuation of the program. A questionnaire was sent to all area offices of Ontario Hydro to determine the adequacy of records kept about tested and treated poles. The results of the questionnaire indicate that the data available are not sufficient for the evaluation, and a survey in the field is necessary to gather the data required.

1. INTRODUCTION

Wood poles used for distribution lines can deteriorate to the point where they need to be replaced. Some reasons for deterioration are: rot can start on the outer shell or in the inner core, woodpecker holes can weaken the structure, lightning or collision of a motor vehicle with the pole can also cause structural damage.

To ensure that poles remain strong enough to carry the conductors under normal and adverse weather conditions, and safe enough to be climbed by linesmen, Ontario Hydro implemented a program to test poles periodically for deterioration. If the pole has deteriorated past a certain threshold then it is replaced with a new pole. If not, it is treated at the groundline with a preservative compound which is thought to delay deterioration of the outside shell. The Distribution Systems Division is interested in assessing the effectiveness of the treatment and has requested the assistance of the Reliability and Statistics Section of the Operations Research Department. In response, a three-phase plan has been proposed to assess the effectiveness of the program.

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The purpose of Phase I is to determine if sufficient data are available to allow a rigorous assessment of the pole testing and treating program. Contingent on Phase I, data will be gathered and evaluated in Phase II. In Phase III, a study will be made to determine an optimum testing and treating program.

Phase I has been completed and the conclusions are detailed in this report. Recommendations for proceeding to Phase II are given.

2. POLE TESTING AND TREATING DATA

In order to effectively assess the pole treating program, (a) a criterion for deterioration must be set, and (b) based on this criterion, treated poles must be compared with untreated poles. This comparison is meaningful only if the poles in the two groups can be matched by age and other factors that may affect deterioration. In addition, sufficient time should have elapsed from the last treatment to allow for possible deterioration to take place. The testing and treating program is done every 10 years, and it is assumed that this represents sufficient time for possible deterioration. The primary goals of Phase I are to establish the existence of matching groups of treated and untreated poles, to determine a variable by which to compare treated and untreated poles, and to determine the availability of appropriate data.

To identify the type of information presently available, a questionnaire was distributed to each of the 48 area offices in Ontario (see Attachment I) to determine the adequacy of the data. A summary of the responses is contained in Attachment II.

2.1 Existence of Control Poles

The pole testing and treating program follows a block maintenance system wherein each area of Ontario Hydro is divided into several blocks. Each of these blocks of poles are designated a year for testing and treatment (Attachment II, Questions 7 and 9). If however, for any reason such as budget cuts, all the poles in the block are not tested and treated in its designated year, these poles remain untreated until the ten year cycle is repeated. The following year, poles are tested and treated in the next block. With further inquiry, it was determined that incomplete testing and treating of blocks was common. Therefore, untreated poles, which will be referred to as control poles, are available.

Many areas have color coded line maps which show the block boundaries and indicate the years when each block was tested and treated. Colors are used to indicate which lines of poles have been tested and treated. Availability of these maps from each area will help identify control poles. However, it is unclear if all area offices have these maps.

2.2 Comparison Variable

A comparison variable must be selected so that treated poles can be compared to untreated poles. Examples of ideal comparison variables are the rate of deterioration of poles and the strength of poles. To date, neither variable has been rigorously quantified, although studies are presently being conducted to calibrate the strength of poles variable/1,2/. Studies have also been conducted using the amount of preservative left in the pole as an indication of deterioration/3/. However, it is not known how this relates to the lifetime of a pole.

Since there are no other quantitative variables, it is proposed that the replacement rate of poles be considered as an index. The replacement rate is defined as the ratio of the number of poles being replaced and the total number of poles. In the pole testing and treating program, when the poles are tested, a decision is made to keep the pole or replace the pole. To make this deci-

sion, a sample is taken from the pole at ground level, then inspected for possible deterioration (amount of rot, preservative remaining). Usually poles are replaced after testing proves that they have deteriorated though, occasionally, poles are replaced because of lightning damage, service upgrades, line relocations, woodpecker holes, etc. (Attachment II, Questions 4, 5, and 6). Only those poles that have been replaced due to deterioration of the outside shell must be considered in the estimation of the replacement rate.

2.3 Availability of Data

To help determine the availability of data, one of the objectives of the questionnaire was to find out if the area offices kept records about the poles and if so, for how long these records are kept on file. It was found that when poles are tested and treated, the information gathered is recorded on a special pole inspection and test/treat form and are kept in the respective area lines offices (Attachment II, Question 1). Eight of the 36 areas who responded have records on file as early as 1971 to 1975 (Attachment II, Question 2). Six are between 1976 and 1980. Twenty-two of the areas have earliest records on file only between 1981 and 1985. Thus, since records that are at least 8 years old are required, most records do not extend back far enough. In addition, the records only exist for poles that have been tested and treated, not for control poles.

Through discussions with representatives of the Distribution Systems Division, it became evident that a number of factors may affect the replacement rates of poles. These factors include ambient conditions such as soil type and weather, species of pole and type of retreatment. Most areas record information about the size, species, class of the pole, year of installation, type of test used, and condition of the pole after inspection (Attachment II, Question 3). In addition, the year of installation, the testing and the treating date can be verified by the dating nail stamped on the pole (Attachment II, Question 8).

3. CONCLUSIONS

- Untreated poles (control poles) are available since all poles in a block are often not tested in the designated year.
- The control poles cannot be located easily since records are only kept about tested and treated poles. Only the color-coded maps may have this information. However, the maps do not contain information about the age of the pole. Also, not all areas maintain color-coded maps.
- Data cannot be obtained from the pole testing and treating records since, in general, they do not extend back long enough.
- Data about the untreated poles cannot be gathered from the records since records were only made about tested and treated poles.
- The replacement rate of poles is the best available variable for comparing treated poles to untreated poles. The deterioration rates, the amount of preservative remaining, and the strength of poles are not calibrated and thus cannot be used as a basis of comparison.

4. RECOMMENDATIONS

There is insufficient information available to enable the location of control poles. In addition, the records for the tested and treated poles are not useful since they do not date back far enough in most instances. Therefore, it is recommended that a survey be carried out to sample

poles in the field. The poles usually have the date of installation and the previous testing date stamped on them. The sample selected will include poles which had not been previously tested and others which had been tested and treated. The sampled poles will be tested to see if they have deteriorated enough to be replaced. Thus, replacement rates can be established for both previously treated and untreated poles and the significance of the difference (if any) can be determined. It is recommended that the study proceed as follows:

- Determine if the color-coded line maps have information concerning which lines of poles were tested and treated.
- Design a survey for sampling poles in the field. This includes deciding how many poles should be tested and where they should be sampled from.
- Sampled poles will be tested for deterioration and a decision will be made whether to replace them or not. In addition to testing the poles, information concerning soil conditions, age of poles, type of installation of pole and species of pole should be collected.
- After the survey is completed, the data should be analysed to assess the treatment program.

In order to have sufficient confidence, the number of poles that need to be surveyed will likely be large because the replacement rates are small. Attachment III contains a description of the sample size calculation and a selection of candidate sample sizes (Attachment III, Table 2). In a survey conducted in 1986, the replacement rate of tested poles was estimated to be 6.8% (Attachment IV). This rate is for all ages of poles.

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ATTACHMENT I

POLE TESTING AND TREATING PROGRAM QUESTIONNAIRE

A study is in progress to determine the effectiveness of the pole testing and treating program. The main objective is to see if the treatment of wood poles at the groundline after 15 years of service is significantly delaying the onset of deterioration. At this stage of the study, information concerning the availability of data is required. Your assistance would be of great value in collecting this information. Please fill out the questionnaire and return to the address stated below by June 15, 1987.

1. Are records made when poles are tested and treated? How are they made? Where are they stored?

2. When were records first made? What is the earliest year on the records which are in the files at the present time?

3. Is the following information given in the records? Please answer yes (Y), most of the time (M), some of the time (S), never (N).

Installation date (or age) of pole	_____
Species of pole	_____
Size of pole	_____
Location of pole	_____
Soil conditions around pole	_____
Type of preinstallation treatment of pole	_____
Strength of pole at installation	_____
When pole was tested	_____
How pole was tested	_____
Was pole treated or replaced	_____
If pole was replaced, reason given	_____
If pole was treated, type of treatment	_____

4. If a pole is replaced after a test, can it be assumed that the pole is replaced because of deterioration?

5. Are poles replaced (discarded) for reasons other than "failing" a test, at times other than following a test?

6. If yes, please provide typical reasons.

7. How does the area office keep track of which poles have been tested and which have not?

8. How is the information about the age of the pole kept? Is the installation date on the pole, is there a map of all the poles in the area with the installation dates, or is another method used? Please describe method.

9. How is it decided which poles are to be tested in a particular year?

10. Please provide additional relevant information below.

Please send the completed questionnaire and some sample records to:

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ATTACHMENT II

A SUMMARY TO THE POLE TEST AND TREAT QUESTIONAIRES

>Question 1

A special pole inspection and test/treat forms are filled out whenever poles are inspected. These records are kept at the Area Lines Office.

>Question 2

Most area offices were not definite as to when the records were first made, only nine recorded some dates.

Year	No. of areas
before 1970	7
after 1970	2

The earliest records kept on file vary among area offices. These are categorized below.

Year	No. of areas
1971-1975	8
1976-1980	6
1981-1965	22

>Question 3

Answers to this question were tabulated under Y (Yes), M (most of the time), S (Some of the time) and N (Never). A frequency table is shown below.

TABLE I

	Y	M	S	N	T
Installation date of pole	30	5	1	6	41
Species pole	39		1	1	41
Size of pole	38	3		1	42
Location of pole	31	4	2	5	40
Soil conditions around pole	24	2	5	10	41
Type of preinstallation treatment of pole	12	2	6	20	40
Strength of pole at installation	10	1	1	28	40
When pole was tested	37	1		5	43
How pole was tested	31		1	10	42
Was pole treated or replaced	34	2		3	41
If pole was replaced, reason given	25	1	1	14	41
If pole was treated, type of treatment	25		1	16	42

Legend:

Y - Yes

M - Most of the time

S - Some of the time

N - Never

T - Total

>Question 4

When a pole is replaced after testing, most of the time it is due to deterioration. The following is a tabulation of the answers to the question, if a pole is replaced after a test, can it be assumed that the pole is replaced because of deterioration.

YES	32
NO	2
Most of the time	11
	45

>Question 5

Answers to the question, are poles replaced for reasons other than "failing" a test, at times other than following a test, are summarized below.

YES	43
NO	2
	45

>Question 6

Poles are replaced other than "failing" a test for the following typical reasons, lightning damage, woodpecker holes, traffic accidents, line relocations, service upgrades, etc.

>Question 7

The area offices follow a block maintenance system. An area is divided into blocks, determined by the are lines foreman. Each block of poles are scheduled for testing and treatment at a designated year. This plan is recorded in a colour coded line diagram map.

>Question 8

Dating nails are attached on every pole containing the data of installation. In some cases, the year the pole was installed in a particular block is indicated on a map or recorded in the pole test and treat data forms.

>Question 9

Poles are tested and treated by following a block maintenance system. A 10-year block system, for example, means one block (10% of the area) is tested and treated on a designated year.

ATTACHMENT III

CALCULATION OF NUMBER OF POLES

To provide for sufficient confidence in the comparison of untreated poles and treated wood poles, the appropriate number of poles that need to be tested must be estimated. In this section, the calculation of the sample size will be discussed and example sample sizes will be computed for various scenarios.

For the purposes of this document, certain assumptions will be made about the poles. It will also be discussed how relaxing these assumptions will affect the sample size. The assumptions are as follows:

- All poles have the same ambient conditions such as soil type and weather conditions.
- All poles are of the same species.
- All poles had the same pretreatment.

Henceforth, the population of poles under consideration for the purposes of the comparison will follow these assumptions.

The comparison of treated poles to untreated poles will be accomplished using the replacement rates of poles. The replacement rate is defined as the number of poles in a population of poles that need to be replaced due to deterioration. Table 1 contains definitions of terms that will be used in the development of the theory. In addition, the population total and the sample total are defined as

$N = N_1 + N_2$ = total number of poles in the population

$n = n_1 + n_2$ = total number of poles in the sample

The proportion of treated poles is compared to the proportion of untreated poles, that is, p_1 is compared to p_2. To do this, a statistical test of the null hypothesis, $p_1 = p_2$ against the alternative hypothesis, $p_1 < p_2$ is performed. Assuming that N_1 and N_2 are very large compared to n_1 and n_2 and, in addition, n_1 and n_2 are large (> 100) then the Z statistic,

$$Z = \frac{p_1 - p_2}{\sqrt{\frac{p_1(1-p_1)}{n_1} + \frac{p_2(1-p_2)}{n_2}}}$$

is compared to the normal distribution to assess significance. The null hypothesis is rejected at the α level of significance if $Z < -Z_\alpha$. In doing this test, the probability is α that the hypothesis is rejected given that the p_1 is really equal to p_2. That is, the risk is α that the data show that the two populations are different when they are truly the same. The probability of making this error, known as type I error is controlled by chosing the level of significance, usually

at 0.05. However, it could also happen that the hypothesis is accepted when it is really false. That is, the data could show that p_1 equals p_2 when they are really different. This is called the type II error. The probability of making this error, β, can be controlled by chosing n_1 and n_2 to be large enough.

Choosing n_1 to be equal to n_2 and doing some algebra, the required sample sizes can be shown to be

$$n_1 = n_2 = (Z_\alpha + Z_\beta)^2 \ (p_1 (1 - p_1) + p_2 (1-p_2))$$

where Z_α and Z_β are the upper α and β percentile points of the standard normal distribution.

It is noted that since it is expected that p_1 is less than or equal to p_2 and most likely p_2 is less than 0.5, then

$$p_1 (1-p_1) + p_2 (1-p_2) \leq 2\ p_2 (1-p_2)$$

Thus, making n larger than necessary to be conservative,

$$n_1 = n_2 = \frac{(Z_\alpha + Z_\beta)^2}{d^2} (p_2 (1-p_2))2$$

It remains to choose d and p_2. It is easier to think of d in terms of a proportion c of p_2, that is, $d = c\ p_2$. The sample sizes then become

$$n_1 = n_2 = \frac{(Z_\alpha + Z_\beta)^2}{c^2} \quad 2 \left(\frac{1}{p_2} - 1\right)$$

Table 2 contains sample sizes for various selections for d and p_2 for $\alpha = 0.05$ and $\beta = 0.1$. These values were chosen among several choices since they are most commonly used. For example if we are looking for a 90% reduction in the replacement rate and it is estimated that the replacement rate for untreated poles is 3%, then roughly 700 treated and 700 untreated poles must be sampled in order to control the probabilities of type I and type II errors to be 5% and 10%, respectively.

TABLE 1

DEFINITIONS OF TERMS

	Treated poles	Untreated poles
Number of poles in population	N_1	N_2
Number of poles in sample	n_1	n_2
Number of poles to be replaced in population	A_1	A_2
Number of poles to be replaced in sample	a_1	a_2
Proportion of poles to be replaced in population	$P_1 = A_1/N_1$	$P_2 = A_2/N_2$
Proportion of poles to be replaced in sample	$p_1 = a_1/n_1$	$p_2 = a_2/n_2$

TABLE 2

SAMPLE SIZES FOR VARIOUS SELECTIONS OF P2 AND C
GIVEN THAT = 0.05 AND = 0.10

c / P2	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
0.001	427353	189935	106838	68377	47484	34886	26710	21104	17094
0.005	85126	37835	21282	13621	9459	6949	5321	4204	3405
0.010	42350	18822	10588	6776	4706	3457	2647	2091	1694
0.015	28091	12485	7023	4495	3121	2293	1756	1387	1124
0.020	20961	9316	5240	3354	2329	1711	1310	1035	838
0.030	13832	6147	3458	2213	1537	1129	864	683	553
0.040	10267	4563	2567	1643	1141	838	642	507	411
0.050	8128	3612	2032	1300	903	663	508	401	325
0.100	3850	1711	963	616	428	314	241	190	154
0.150	2424	1077	606	388	269	198	152	120	97
0.200	1711	761	428	274	190	140	107	84	68
0.250	1283	570	321	205	143	105	80	63	51
0.300	998	444	250	160	111	81	62	49	40
0.350	794	353	199	127	88	65	50	39	32
0.400	642	285	160	103	71	52	40	32	26
0.500	428	190	107	68	48	35	27	21	17

ATTACHMENT IV
PROVINCIAL SUMMARY

POLE TESTING AND TREATMENT : 1986 AREA SURVEY

44 AREAS (4 FORMS NOT RECEIVED IN TIME, ALL FROM CENTRAL)

NOTES:

Replies given below should be your best estimates of future amounts, based on the area's previous experience, projections of future developments, budget/manpower constraints, etc. I realize that these amounts are uncertain, so where applicable you can give ranges instead of single figures, e.g. "100 - 200 poles", not "153 poles" (when processing the surveys, I will assume a 75% confidence level for ranges). I also realize that estimates for 1992-96 will be much more uncertain than for 1987-91. Make your best guess!

Please feel free to supply any additional information, suggestions, or opinions about the pole testing and treatment program that could help in determining the optimum cycle length and the future benefits of groundline treatment.

CONFIDENCE OF FIGURES
G = GOOD
M = SO-SO
P = POOR

QUESTIONS:	1987-91	1992-96	
1. How many rural and LT poles in the area?	1.29M	1.35M	G
2. What percent of the existing plant is full-length-penta-treated pine?	71.4%	80.3%	G
3. What percent of new poles ordered are full-length-penta-treated pine?	94.0%	92.0%	G
4. How many poles are replaced per year due to groundline rot?	4.0k	4.9k	M
-what percent of these are treated pine?	28.4%	38.4%	P
-what percent have had groundline treatment?	61.1%	70.1%	P
-how old are they? (FIGURES NOT WEIGHTED)	36.1 Yrs	37.0 Yrs	G
5. How many poles are replaced per year due to accidents, storms, etc.?	1.5k	1.5k	G
-how old are they? (UNWEIGHTED AVG.)	20.8 Yrs	22.0 Yrs	G
6. How many poles are removed per year due to line betterments, relocations, etc.?	14.5k	14.1k	G
-how old are they? (UNWEIGHTED AVG.)	26.8 Yrs	27.7 Yrs	G
-what percent of them are re-used?	20.7	20.9	M
-what percent are treated when re-used?	5.0	5.1	G
7. How many in-service pole failures per year due to groundline rot?	392	413	M
8. Current replacement costs per pole?			
-labour $377.69	T&WE & OTHER - $201.70	≃$900/pole	
-material $315.70			
9. How many poles tested per year?	76.6k	83.7k	G
-what percent of these are replaced?	6.8%	6.7%	M
10. Do you use the injection spade?			
-if so, what percent of the area's poles can be treated with the spade? (1985)	85%	85%	M
11. Current testing costs per pole?	OTHER COSTS		
-labour $17.64	(MOSTLY T&WE)	Combined test & treat costs	
-material $ 6.61	$2.56	≃$27/pole	

12. What are the likely consequences of premature pole failures in your area due to groundline rot? (injury/risk of injury, damage to Hydro/public property, service interruption, etc.)

13. Describe the Area's environmental conditions:
-soil: (rock/gravel/sand/silt/clay/organic/moist/dry)
-climate: (warmer/cooler),(drier/more humid) than Provincial average
-drainage (in general): (good/poor)